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Analysis on Composition and Pattern of Agricultural Non-point Source Pollution in Liaohe River Basin, China

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Abstract

The composition and spatial pattern of agricultural non-point source (NPS) pollution was studied in Liaohe River basin which is representative of areas of intensive NPS pollution in Northeast China. Selecting COD and ammonia nitrogen as the major pollutants, the export coefficient method and GIS spatial analysis methods were utilized to analyze the component composition and spatial distribution characteristics of NPS pollution in Liao River basin. The results showed that farmland runoff was the most significant source for the agricultural NPS pollution in the study area. Over 60 percents of the pollution loading was distributed in the Liaohe River mainstream area, and the pollution intensities were stronger in Hunhe River downstream and Liaohe River stem downstream plain sub-basins in Central-Western Liaoning province than in Hunhe River upstream and Taizihe hilly sub-basins in eastern Liaoning province.

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Keywords: agricultural non-point source pollution; loading; composition; pattern

1. Introduction

The main NPS pollution in Liaohe River is agricultural NPS pollution, and most NPS pollution happens in the middle Liaohe River basin within Liaoning province, according to NPS pollution investigation for grade A areas in national water resource comprehensive planning [1]. As the natural conditions and social economical conditions vary in the basin area, the composition and spatial

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distribution of pollution differ. It is necessary to carry out further study on agricultural NPS pollution in Liaohe River basin, especially on its compositions and spatial pattern.

The export coefficient model is an empirical model [2-4], and depends less on experiments and relevant information on erosion, pollutant migration and transformation. As a black box method, it can utilize the easily obtained information on land use status, fertilization, and population to estimate precisely, to some extent, the output of basin pollution, avoiding the complexity from NPS pollution process. It is widely used as a feasible method for long-term study on NPS pollution on middle and large basins [5-10].

In this paper, the export coefficient method was utilized to estimate the agricultural NPS pollution loading of Liaohe river basin, and GIS spatial analysis methods were utilized to analyze the spatial distribution characteristics of the pollution loading. The pollutant source types studied included rural life, farmland runoff and livestock.

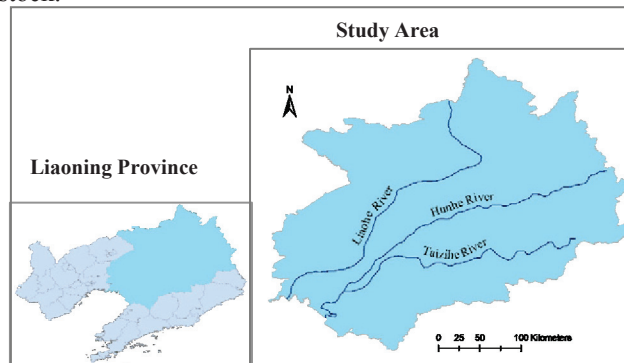


Fig. 1. Location of the study area

2. Materials and Methods

2.1. Study area

The Liaohe River mainstream is 512 Km long, running through Liaoning province, China, and the basin area is 69,100 Km². The terrain of the basin declines from northeast to southwest, with its northeastern part being hilly and its central and southern parts being flat. The basin belongs to a temperate monsoon climate, with the annual precipitation varying from 350mm to 1000mm, 65% of which occurs between April and September each year. The basin occupies all or most of the areas of the municipal cities of Tieling, Shenyang, Fushun, Anshan, Liaoyang, Benxi, Yingkou and Panjin, and smaller parts of Fuxin and Jinzhou. The population over the basin is about 24 millions and the area is one of the most important industrial and agricultural production bases in China.

2.2. Method

The formula for agricultural NPS pollution from Export Coefficient method is

$$L = \sum_{i=1}^n Ei[Ai(Ii)] ,$$

where L represents the nutrition loss, Ei represents the export coefficient of nutrition source i which is the nutrition delivery ratio for each type of pollution source (e.g. farmland, livestock or population), Ai represents the area of land use type i, quantity of livestock type i or population number, and Ii represents

nutrition production of unit pollution source type i , i.e. pollution source intensity coefficient or pollutant generating coefficient.

We obtained the relevant data of 2007 on population, livestock and farmland of every district or county in the study area from Liaoning Statistical Yearbook of 2008 [11]. COD and ammonia nitrogen were selected as the main pollutants. By referring to relevant literatures and taking into account the natural and economical conditions of the river basin, we determined the export coefficients and pollutant generating coefficients of COD and ammonia nitrogen generated from rural life, livestock and farmland runoffs respectively.

We analyzed the NPS pollutant composition in the study area by calculating the contribution of main pollutants from different pollution source, which were determined through calculating annual COD and ammonia nitrogen export loadings from rural life, livestock and farmland runoff. The basin is divided into six sub-basins according to its natural characteristics which are Liaohe River stem upstream, Liaohe River stem downstream, Hunhe River upstream, Hunhe River downstream, Taizihe sub-basin and Daliaohe sub-basin. We calculated the pollutant loading and loading intensity for each of them and analyzed the agricultural NPS pollution spatial variability of basin in the GIS spatial analysis model.

3. Results and Discussion

3.1. Determination of main pollutant export coefficients for agricultural NPS pollution in Liaohe River Basin

- The export coefficients of pollutants from rural life

The rural life pollutant generating coefficients were determined as 16.4 gram per person per day for COD and 4.0 gram per person per day for ammonia nitrogen, based on Technical Outline for Preparation of "National Drinking Water Source Protection Plan" [12]. There are no sewage treatment facilities in the rural areas, thus the export coefficient was determined as 1 (Table 1).

Table 1. The export coefficients and pollutant generating coefficients of rural life

export coefficient	pollutant generating coefficient of COD (g/p·d) ^a	pollutant generating coefficient of NH ₃ -N (g/p·d)
1	16.4	4

a. Gram per person per day

- The export coefficients of pollutants from farmland

The farmland pollutant generating coefficients were determined based on Technical Outline for Preparation of "National Drinking Water Source Protection Plan" [12], and modified according to farmland gradient, soil type, precipitation and fertilization level (see Table 2). The export coefficient for the NPS pollution in Liaohe River basin was determined as 0.58, which is the smallest experiment value in Hao's work in the same area (see Table 3) [1].

Table 2. Modified pollutant generating coefficients of farmland runoff

Modifying factors	Modified coefficients		
	<25°	25°	>25°
Gradient	1.0-1.2	1.2	1.2-1.5

soil type	loam	Sand	Clay
	1	1.0-0.8	0.8-0.6
Precipitation	<400mm/yr	400-800mm/yr	>800mm/yr
	0.6-1.0	1.0-1.2	1.2-1.5
fertilization	<25kg	25-35 kg	>35kg
	0.8-1.0	1.0-1.2	1.2-1.5

Table 3. The export coefficients and pollutant generating coefficients of farmland runoff

export coefficient	pollutant generating coefficient of <i>COD</i> (kg/ha·yr)	pollutant generating coefficient of <i>NH3-N</i> (kg/ha·yr)
0.58	150	30

a. Kilogram per hectare per year

- The export coefficients of pollutants from livestock

As there is almost no sewage treatment facility in the study area, the pollutant generating coefficients of livestock was estimated as those of scattered livestock. The local farmers take the livestock emissions as manure, therefore the pollutant export was calculated as 12% of the emissions generated, according to *Technical Outline for Preparation of "National Drinking Water Source Protection Plan"* [12]. The pollutant generating coefficients for pigs, cattle, and sheep were determined according to GB18596-2001 *Discharge standard of pollutants for livestock and poultry breeding* and *Practical Handbook of Fertilizer* (see Table 4) [13-14].

Table 4. The export coefficients and pollutant generating coefficients of livestock

Livestock type	export coefficient	pollutant generating coefficient of <i>COD</i> (g/i·d) ^a	pollutant generating coefficient of <i>NH3-N</i> (g/i·d)
pig	0.12	50	10
cattle	0.12	500	100
sheep	0.12	16.7	3.3

a. Gram per individual livestock a day

3.2. Analysis on composition and pattern characteristics of Agricultural NPS pollution in the study area

- Composition of pollution source

COD loading generated by agricultural NPS in the study area was 321,986 tons in 2007 (see Table 5), out of which the farmland runoff contributed 57.2%, the livestock and rural life contributed 42.8%. The farmland runoff was the most significant contribution and the livestock contributed more than the rural life. The agricultural farmland runoff was also the main agricultural NPS pollution factor in each sub-basin. The farmland runoff occupied over 60% in Liaohe Rive mainstream, and less than 50% in Hunhe downstream and Taizihe sub-basins. Except Hunhe River upstream, each sub-basin's pollution contribution by livestock was greater than that of rural life (see Fig 2).

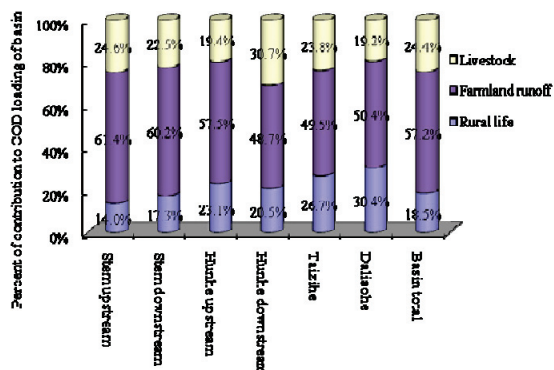


Fig. 2. The composition of COD loading source in Liaohe River basin

Ammonia nitrogen generated by agricultural NPS pollutants was 66,997 tons (see Table 5), among which 55% was contributed by farmland runoffs and 45% by livestock and rural life. As shown in Fig 3, the composition of pollution sources for ammonia nitrogen is similar to that for COD.

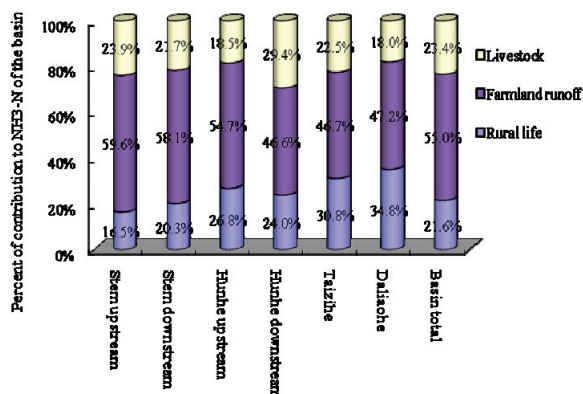


Fig. 3. The composition of NH₃-N loading source in Liaohe River basin

The study area is located in northeastern China with relatively large arable farmland per capita and a small agricultural population density, and the consumption level of people there is relatively low. That may be the reason why farmland runoff contributed the largest part in Liaohe River NPS pollution composition, whereas livestock and rural life contributed less.

- Spatial pattern characteristics of pollution loading

From the spatial distribution, the NPS pollution of the study area was distributed mainly in Liaohe River mainstream, with its upstream and downstream respectively contributing 44.2% and 19.4% of Liaohe River Basin's total agricultural NPS pollution. Next comes Taizihe sub-basin, which occupied 16.0%. The agricultural NPS pollution load was also serious in Hunhe River downstream but comparatively little in Hunhe River upstream and Daliaohe sub-basin (see Table 5).

Table 5. The distribution of main pollutants in Liaohe River basin

Sub-basin	COD (t/yr.)	NH3-N (t/yr.)	percent
Stem upstream	142468	29364	44.2%
Stem downstream	62500	12973	19.4%
Hunhe River upstream	15399	3235	4.8%
Hunhe River downstream	38508	8048	12.0%
Taizihe	51543	10910	16.0%
Daliaohe	11570	2467	3.6%
Basin total	321988	66997	100.0%

The pollution loading of the basin outlet is influenced by the basin's area on one hand and by the basin's population density and industrial structure on the other. The pollution loading intensity represents the pollution export per unit area and could be used to further analyze the characteristics and causes of agriculture NPS pollution spatial variability.

The COD loading intensity in Liaohe River Basin varied greatly in the range of 0.0134-0.0717 tons per hectare per year. The COD loading intensity was greatest in Hunhe River downstream and smallest in Hunhe River upstream (see Fig.4). The agricultural NPS pollution loading intensities in the study area were classified into three levels according to their determined values (see Fig.5). Hunhe River downstream and Liaohe River Stem downstream, which are located in central Liaoning province with best agricultural conditions and densest agricultural population, had greatest agriculture NPS pollution intensities and belonged to level I. Hunhe River upstream and Taizihe basin are located in hilly eastern Liaoning province, where both arable farmland per capita and agricultural population density are lower, had the smallest NPS pollution intensities and belonged to level III. Liaohe River stem upstream and Daliaohe sub-basin are located in the transition zone varying from eastern hills to western plains in Liaoning province, where the agricultural condition falls between those of level I and level III, belonged to Category II.

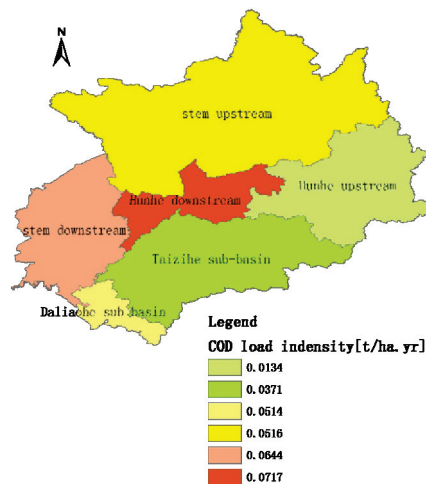


Fig. 4. The map of agricultural NPS intensity distribution in Liaohe River basin

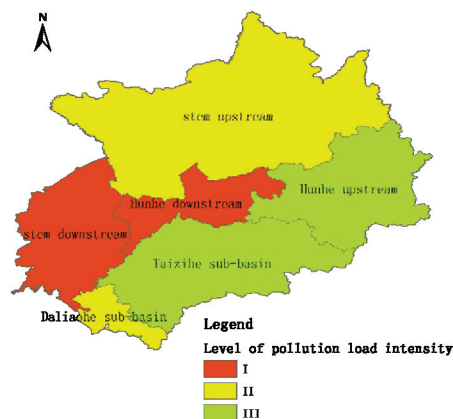


Fig. 5. The map of agricultural NPS intensity levels in Liaohe River basin

4. Conclusion

The analysis on the composition and spatial distribution characteristics of agricultural NPS pollution in Liaohe River basin showed that farmland runoff contributed the most part to the pollution loading in the study area, and the livestock and rural life contributed less. The agricultural NPS pollution distributed mainly in Liaohe River mainstream and Taizihe sub-basins. The pollution intensities were strong in Liaohe River mainstream, Hunhe River downstream and Daliaohe plain sub-basins, and weak in Hunhe River upstream and Taizihe hilly sub-basins.

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